Beyond human vision

Computer vision systems offer new, innovative approaches to conducting inspections

New technologies in the pipeline for use in meat inspection - discussions from a workshop about the future of meat inspection at the SafePork Conference in Rennes, France, in October 2025.

By Lis Alban et al.

The four organizers of the SafePork workshop, from the left: Jalusa Deon Kich (Brazil), Diana Meemken (Germany), Bojan Blagojevic (Serbia), Lis Alban (Denmark) and Madalena Veira-Pinto (Portugal). *Foto: SafePork*

The 15th SafePork Conference was held in Rennes, France, between 6 and 8 October 2025. One of this year's pre-conference workshops was dedicated to the modernization of meat inspection with a special focus on the potential use of new technologies. Traditionally, meat inspection has been performed manually by veterinary inspectors, trained to identify diseases, contamination, and any defects in carcasses or viscera. Indeed, manual inspection forms the cornerstone of most food safety inspection practices. However, manual inspection is inherently subjective, influenced by factors such as operator experience, fatigue, and environmental conditions, resulting in variability in inspection performance. Moreover, manual inspection is not practical, as the slaughter line speeds in abattoirs are very fast. Computer vision systems (CVS) and other AI-based methods represent new approaches to inspection. CVS integrates the use of high-resolution image acquisition with real-time image analysis, using advanced AI algorithms, allowing automated inspection decisions. Such systems can potentially improve the quality of the meat inspection process through higher objectivity and data continuity, with enhanced scalability. In line with this, the European regulations on official control and meat inspection now permit pilot projects to explore innovative technologies to enhance and support meat inspection (1,2).

The presentations given at the workshop demonstrate the progress of these technologies and how they may be applied at an abattoir, either as support tools for meat inspectors or to help abattoirs ensure animal welfare, prior to slaughter. Moreover, the challenges and steps ahead for non-EU countries, including Brazil, Kenya and Vietnam are explored.

Monitoring of animal welfare through use of CVS

While a key focus of meat inspection is on animal disease and food safety, abattoirs also serve as critical observatories for monitoring animal health and welfare. Pathological findings in pig carcasses offer valuable insights into on-farm conditions, support feedback loops for farmers and veterinarians and enable large-scale epidemiological studies (3).

The project presented by Sergio Ghidini from the University of Milano, Italy, aims to integrate CVS outputs with Italy's ClassyFarm platform, a risk-based surveillance system that already collects data on animal welfare, biosecurity, antimicrobial use, and diagnostics. For more information about ClassyFarm, please see: *https://www.classyfarm.it/index.php/en/*. Five high-resolution cameras installed in two industrial abattoirs in Lombardy capture images of key anatomical sites such as the tail, skin, offal, and thoracic wall. Expert veterinarians annotate each image using polygonal labelling to ensure accurate training of the CVS models. After validation, these models are intended to be embedded into detection hardware for real-time analysis. This integration promises to enhance disease monitoring and optimize official control, hence, marking a significant step toward data-driven, technology-enhanced meat inspection systems that enable real-time data acquisition and analyses.

Detecting contamination by video image analysis

Matthias Upmann from the OWL University of Applied Sciences and Arts, Germany, presented a study investigating the detection and reduction of contamination of intestinal contents, stomach contents, bile, and tubular rail grease on pig carcasses using video image analysis and steam-vacuum treatment (4). The so-called "Pig-Inspector" system, equipped with five high-resolution cameras and an AI-based contamination detection algorithm, was installed between the evisceration and the official meat inspection step. For more information about "Pig-Inspector", please see: *https://www.clkgmbh.de/en/food/piginspector*. Comparative analysis revealed discrepancies between the outcomes of the experts and the "Pig-Inspector". While the AI's results occasionally overestimated contamination, it proved valuable for pre-sorting carcasses before official meat inspection.

The second part dealt with the efficacy of steam-vacuum treatment for carcass decontamination. Artificially contaminated carcass surfaces were treated for 2, 4, or 6 seconds, and the results showed that a 6-second treatment significantly reduced microbial loads, achieving levels comparable to those of hygienically slaughtered carcasses. However, visible residues, such as color deviations on the carcass from bile or grease, persisted post-treatment (5). In conclusion, the integration of AI-based video image analysis with steam-vacuum treatment offers a promising approach to enhance microbiological safety in pork production. While the AI system requires further refinement, its potential for automating contamination detection and targeted decontamination is evident.

Automized registration of pleurisy in pigs at abattoirs

Manual detection or scoring of porcine pleurisy involves registration of lesions exceeding first size (15 cm). This method is constrained by time and subjectivity, leading to inconsistent data with limited epidemiological value (6). As an alternative, the Norwegian EyeAM project (2022–2025) has evaluated an AI-based system called ADAL (Automated Detection of Abattoir Lesions), which is designed to objectively score pleurisy using image capture.

The project, presented by Andrea Capobianco Dondona from Farm4Trade in Italy, combined a collaborative robot for carcass imaging and a pre-trained convolutional neural network (CNN). Trained on 5,902 annotated images, the CNN achieved 85.5 % accuracy. Over eight months, ADAL's predictions were benchmarked against registrations made by official veterinarians (OVs) and auxiliary staff in two Norwegian abattoirs. ADAL detected pleurisy at nearly double the rate, due to its ability to register all lesions. The work represents a successful field validation study of a fully automated pleurisy scoring system for use in pigs. ADAL demonstrated strong potential for consistent, objective lesion recording, enhancing meat inspection, and providing actionable feedback to producers. Key challenges include refining image acquisition, expanding lesion detection capabilities, and linking findings to individual animals. These steps are crucial to fully realize the operational and economic benefits of automation in meat inspection.

Validation of CVS systems for meat inspection

CVS requires validation before being widely adopted in meat inspection. Validation typically involves comparing system performance to established reference standards using metrics such as sensitivity and specificity. However, such validation is challenging in meat inspection due to the absence of a definitive gold standard, as both meat inspectors' assessments and CVS outputs contain inherent uncertainties. Traditional methods, including agreement tests and conventional diagnostic metrics such as precision or accuracy, implicitly assume the presence of a true reference standard and thus are unreliable in validation scenarios involving novel CVS technology.

Abbey Olsen from the University of Copenhagen, Denmark, outlined an example of an approach to overcome these obstacles. She explained that Bayesian latent class analysis (BLCA) offers an alternative approach and does not require a gold standard. BLCA assumes that the CVS and the meat inspectors are imperfect tests. When using BLCA, the true prevalence and diagnostic performance of CVS and veterinary inspectors are estimated simultaneously. To illustrate the BLCA, Abbey Olsen presented a Danish case study investigating the detection of chronic pleurisy in finishing pigs. It was shown that the CVS evaluated, which is called "Vision" and is developed by the Danish Technological Institute, performed very well in comparison with the meat inspectors (7).

Use of CVS during pig slaughter

Derk Oorburg from Vion Food Group in the Netherlands presented several technological AI solutions

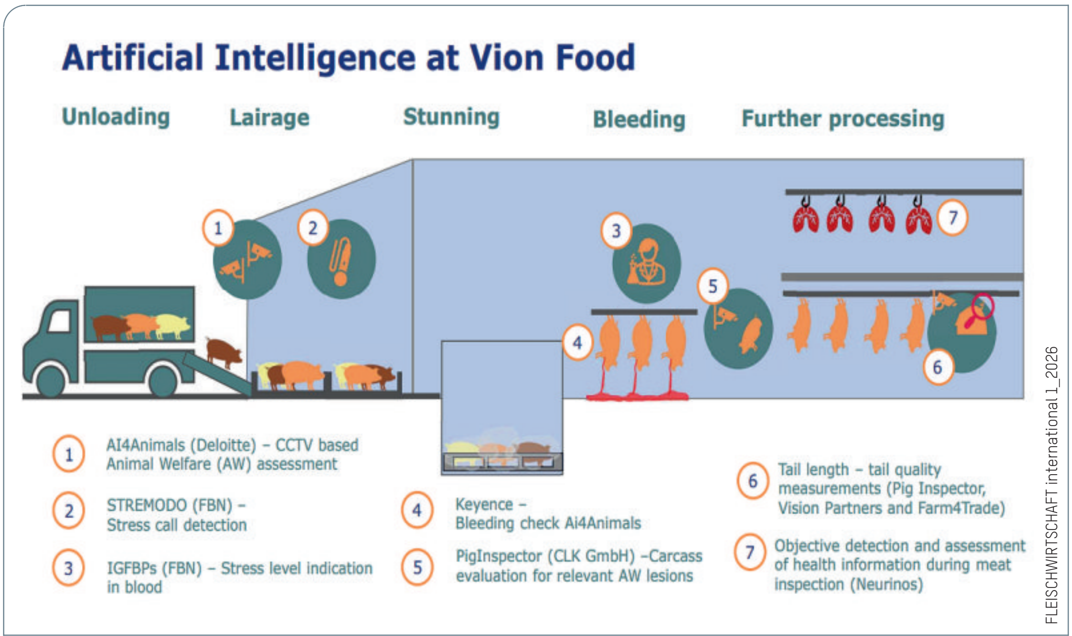

Fig. 1: Illustration of various artificial intelligence tools that are either implemented or being tried out at Vion's pig abattoirs – Image based on NVWA figure (Sensortechnology at the slaughterhouse, RCVWA/2022/8645, kindly provided by Derk Oorburg, Vion). *Source: Vion*

already in use at Vion abattoirs (Fig. 1). In the lairage, cameras (AI4Animals) and acoustics (Stremodo) are used to show compliance with standard procedures for animal welfare and to identify areas for improvement, although deficits are still detected primarily by the Food Business Operator (FBO) staff and OVs. In addition, a stress-level indicator (IGFBPs) is being tested using blood test results, and the success of bleeding (Keyence) is assessed by a camera-based evaluation of the blood flow.

The "Pig-Inspector" system, which was also mentioned earlier, is used on the slaughter line to detect animal welfare-related lesions on the carcasses via camera systems, again based on AI. Tail length and quality (intact or damaged), as well as various organ findings, are also detected using cameras and analyzed using AI, which in the future could assist OVs during meat inspection. Taken together, these tools enable direct, targeted, and standardized interventions by abattoir personnel and can assist OVs in evaluating animal health and welfare in real time. To optimize the handling of the animals during unloading, virtual reality glasses are also used, to enable the abattoir staff to experience the lairage and the abattoir environment the way animals do.

Status of the use of AI in meat inspection in Europe

Geraldine Duffy from Teagasc Food Research Centre in Dublin, Ireland, presented a review on the use of CVS to support PMI in Europe, focusing on systems internationally commercially available or under research and development. The review included an assessment of the feasibility and challenges of implementing CVS, and was based on insights from meetings with researchers, meat inspectors, policy makers, and FBOs (8). The review highlights that the CVSs under development for pig PMI are currently focused on the detection of findings related to pneumonia, pleurisy, faecal contamination, and tail lesions. The needs for and potential benefits of CVS are related to the increasing speed of slaughter lines in this sector. CVS has the potential to reduce the inspector's subjectivity and increase the sensitivity of meat inspection, performing it faster, while capturing and sending data back to farms more efficiently.

Challenges limiting the uptake of CVS in PMI include the lack of adoption by many EU Member States of visual-only inspection of low-risk animals. This is related to the lack of systems for risk categorisation of animals presented for slaughter and the lack of acceptance by the 3rd countries, which still require traditional inspection. There may be infrastructural constraints in the abattoir, such as space needed to locate cameras and adequate lighting. Moreover, the new systems require huge investments to develop algorithms that must be validated under real abattoir conditions. Additional challenges include low technology readiness, limited in-house IT expertise, and insufficient capacity to store large datasets, including images, alongside concerns about data privacy and security. Nevertheless, the use of AI and digitalisation in PMI is progressing rapidly and significant opportunities are emerging.

Challenges and solutions from hygiene intervention

In Kenya, pork serves as a significant protein source, and although the current per capita consumption is 0.4 kg (9), the consumption is expected to quadruple by 2030. Most pigs are raised by small-scale farmers and subsequently slaughtered at informal slaughter slabs, typically processing fewer than 30 pigs daily. These slabs face substantial hygiene challenges, including inadequate water supply, poor drainage, lack of cold storage, insufficient sanitation, limited equipment, minimal personal protective equipment (PPE) usage, and low awareness of zoonotic risks (9).

Alice Kiarie, from the International Livestock Research Institute in Kenya, presented results from a randomized control trial dealing with hygiene in traditional abattoirs (n=26), comparing control, training/equipment/monitoring (TEM), and TEM plus worker incentives (TEM + I) groups. The intervention results demonstrated improved worker hygiene, PPE compliance, facility cleanliness, and slaughter practices, though reductions in microbial contamination were inconsistent and not statistically significant. Incentives modestly enhanced workers' behavioral adherence. Customer perception of improved hygiene correlated with increased business activity.

These findings indicate that participatory training and monitoring can meaningfully improve abattoir practices. Achieving consistent microbial control, however, will likely require additional measures, including investment in infrastructure, pre-slaughter animal cleaning, and post-slaughter decontamination protocols.

In Vietnam, traditional pig abattoirs are small- to medium-scale, processing 10 to 40 pigs per day. These facilities supply around 60 to 70 % of fresh pork sold in traditional markets (10); however, they face major risks of microbial contamination due to poor hygiene practices and limited regulatory management. Many workers lack basic food safety knowledge, and enforcement of hygiene standards by local authorities remains weak (11).

To address these challenges, a low-cost intervention was implemented across 16 abattoirs. The approach included training, equipment support, monitoring, and small financial incentives. Workers received interactive hygiene training; stainless-steel grids and behavioral nudges posters were provided to facilities. Compliance was monitored and recorded over a short period, and workers received a modest financial incentive.

Results showed improved hygiene practice scores among the intervention group. There were also downward trends in microbial contamination, including *Salmonella* and total bacterial counts

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on carcasses. Financial incentives had a limited effect on sustaining behavior change, while training and monitoring had a more consistent impact. This study suggests that low-cost measures can improve hygiene practices in traditional abattoirs. However, further actions are needed, which include upgrades to infrastructure, pre-slaughter animal cleaning, post-slaughter decontamination, and stronger regulatory oversight for sustainable food safety improvements along Vietnam's pork value chain.

In Brazil, the pig sanitary inspection system faces challenges due to the number and geographic distribution of abattoirs, requiring coordinated actions to maintain inspection effectiveness. In 2024, Brazil exported 1.3 million tons of pork. To address these demands, the Department of Inspection of Animal Products (DIPOA) has invested in modernizing and strengthening the national inspection system. Key actions include updating official programs such as the National Pathogen Control Program and regulation, including risk-based inspection (RBI), exemplified by the RBI Procedures Manual, which specifies establishment duties and audit processes (12).

A new federal law has established the basis for own check programs under official supervision, fostering shared responsibility through audits. In addition, DIPOA has developed a regulatory framework to support technological innovation, providing companies with a clear process to obtain approval for new technologies. A virtual training platform now supports continuous training for official inspectors. Standardization has progressed through updated inspection manuals and a project to harmonize post-mortem lesion identification in pigs. Modernization, however, requires careful management of innovations to ensure food safety while new technologies are adopted. Well-defined regulations, validated methods, professional capacity-building, business operator accountability, and robust audits remain essential pillars for reliability and transparency.

CVS is in the pipeline, but there are challenges

Use of CVS is a rapidly developing area as a support tool in meat inspection and overall meat safety assurance. However, the integration of CVS into meat inspection requires regulatory approval, which necessitates the generation of evidence demonstrating that CVS outputs meet or exceed the accuracy and reliability of traditional inspections. Ultimately, the new technologies have a great potential to lead to improvement of public health and animal health, and welfare in a cost-effective way.

Many European countries and their meat industries have already invested significantly in new technologies and are moving towards risk-based meat safety assurance systems. The situation is notably different in low- and middle-income countries and other overseas regions, including some that are also large pork producers.

Exchange of ideas among researchers, policy makers, and meat industry and their collaboration is a prerequisite for the development and successful implementation of new technologies in meat safety assurance. The SafePork conference represents a brilliant platform for such an exchange. The next SafePork conference will be held in Hanoi, Vietnam, in 2027, marking the first time the conference will take place in Asia. It is expected that a workshop on the modernization of meat safety and control will be offered again to all those interested in the topic.

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